

The Implementation of Ergonomics as a Sustainable Competitive Advantage in the Clothing Industry

Kem Ramdass

Faculty of Arts, Design and Architecture, University of Johannesburg, Johannesburg – South Africa

Abstract--The manufacture of clothing, along with the closely associated activities of fibre and textile production, continues to be one of the driving forces of industrialisation throughout the developing world. At the same time, the clothing industries of many developed consumer industries are fighting to maintain their share of the total value (as opposed to volume) which is created throughout the entire chain of apparel design, manufacturing and distribution. In order to accomplish this objective, managers are empowering employees to take responsibility on productivity and performance. By creating a workplace that is conducive to achieve this performance, in consideration of health and safety, work design and productivity, the implementation of ergonomics can become one of the sustainable competitive advantages in the clothing industry. Integrating ergonomics into a plant's culture can cut worker's compensation costs, reduce lost time, improve productivity and quality and strengthen labour-management relations. The investigation focused on gathering information relating to workers in the different sections of clothing manufacture from incoming raw materials to dispatch of finished goods. The objective was to highlight the plight of the clothing manufacturing employees and to provide workable solutions that could be implemented in order to improve their health and safety. A cross sectional analytical survey was conducted using direct observation, discussion and questionnaires to gain insight into ergonomic related illnesses experienced by employees.

I. INTRODUCTION AND BACKGROUND

The clothing, textile and footwear industries in South Africa were protected by tariffs that were implemented by the National Party government before 1994. The government supported the industry through the Industrial Development Corporation (IDC) that provided incentives for the clothing and textile industry. Nowadays, it is imperative to be actively involved in continuous improvement. The new economy is becoming attuned to "getting more out of less." The clothing industry globally has undergone rapid change within the past few decades. The production of fashion has evolved into a multi faceted industry that is not only concerned with the manufacture of clothing but also the systems of production, distribution, diffusion, reception, adoption and consumption which drive the fashion industry. The South African Clothing and Textile Workers Union (Sactwu) estimates 13400 jobs were lost in the sector in the first 11 months of 2009. SACTWU researcher Etienne Vlok says that in the mid-2000s, the industry was losing about 20000 jobs a year, but in the past three years' this has dropped to between 12000 to 14000 jobs a year [9;29;36].

Changes in the global economy enabled the requirement

for flexibility, adaptability and innovation that led to new education and training demands in order to remain competitive [26;32]. The most significant demand in a continuously changing industry is the proposed need for a highly skilled labour force that has the ability to employ new knowledge, technologies, business improvement methodologies and ultimately add value to existing goods and services. Essentially, these skills and capabilities are developed through a broad general higher education system [33;34].

There are a number of process improvement methodologies that can be applied in clothing manufacture. However, the leadership of organisations require a fundamental insight into the benefits derived through the implementation of such methodologies. Unfortunately, from a South African context, 57% of the cut, make and trim organisations (CMT) operate in a primitive manner, ignoring the concept of process improvement skills development. Process improvement methodologies appear to have a negative connotation to 57% of the CMT manufacturers operating in the clothing industry in the Durban metropolitan area [40].

II. LITERATURE REVIEW

The future of the clothing industry, including the textile, leather and footwear industry is at stake due to national and international competition. Workplaces are based on "efficient movement of product" or best locations for machines. This is done without giving the thought to how people are supposed to fit into their workplace. Issues such as injuries, errors in production (repairs) and efficient motions are often neglected. People are expected to adapt themselves to fit into whatever arrangement has been devised, believing that it has no associated costs. Space limitations are a major contributor to poor efficiencies. Crowding of the workplace with pre-cut components of garments aggravate low efficiency. Some tasks require operator training in contortionist sewing techniques which is done in the workplace. The human body cannot adapt to every situation. People have differences and they have limitations and this issue is not evaluated thoroughly before contracting people on the job [35].

Organisations are feeling the inefficiencies and loss of productivity due to poor application of ergonomics. Workplaces must be designed to be human friendly as employees spend approximately one third of their lives at the workplace. A sound understanding of ergonomics and the work activity being studied is necessary [22].

The best way to make ergonomics an integral part of plant culture is to develop a plant-wide programme. Successful ergonomics programmes share features that are critical for their success and it can lead to competitive advantage. It is the researcher's intention to emphasize the importance of ergonomics and its associated illnesses and its application for the benefit of all stakeholders in industry through and exploratory research design.

Technology has always been key to this competitive struggle and is still largely controlled by the "older" established industries of Japan, Europe and the USA. However, the ease and speed with which young industries have been able to absorb and master advances in machine and process technology throughout the 1980's have turned the attention of these industries to new modes of competition based on organisational know-how and systems as much as upon cost and productivity. Information technology in all its guises lies at the heart of much of the new thinking. An explosion of capabilities in that area is now shaping patterns of development through the 2000's.

The application of these new technologies is having a profound social impact, not only upon the total numbers and location of those employed in clothing manufacture, but also upon the skills, training and management needs of organisations. Almost all industrial manufacturing facilities use some type of work or labour standards to measure productivity and forecast costs. Traditionally this has been the domain of industrial engineers or work-study officers, who analyse the situation and use various methods to arrive at a standard time. Proper work standards are often a necessary part of ensuring the economic efficiency of a manufacturing company. Jobs with high-energy expenditure and whole-body fatigue are the primary cause of increased costs and loss of productivity [24].

A. The many meanings of ergonomics

In the South African clothing industry ergonomics can be used interchangeably with the term workplace engineering – meaning designing workplaces and tasks that are compatible with human capabilities and limitations. A formal definition of the term ergonomics, coined in the United Kingdom in 1950, is the study of human characteristics for the appropriate design of the living and work environment [22]. Ergonomics makes use of a number of disciplines, such as mathematics, engineering, life sciences and behavioral sciences. Each of these contributes to identifying, evaluating, and solving worker-machine interactions. The objective of an ergonomics program is to design a system in which the workplace layout, work methods, machines, and equipment, and the work environment (such as noise and illumination) are compatible with the physical and behavioral limitations of the worker. The better this fit the higher the level of safety and work efficiency [30].

The researcher has been widely exposed to the clothing manufacturing industry and has experienced labour inefficiencies due to poorly designed workplaces. In

consultation with available literature, it has become apparent that ergonomics is discussed on a broad scale covering a multitude of issues applicable to industry in general. The researcher has decided to direct his efforts towards the application of ergonomics in the South African clothing industry. This industry is in dire need of constructive effort to survive.

B. Medical effects of poor ergonomics

An investigation at Justin Footwear Industries of Fort Worth, Texas, indicated that soft tissue injuries represented 95 percent of the claims filed within the 1300 employee footwear division between 1993 and 1995. In 1993, 84 claims totaled approximately \$814 000. A full time workplace engineer was hired who changed workstations and assisted in redesigning tools and workplaces. Employees fill out medical history and condition questionnaires before completing a series of tests to measure the range of motion in their shoulders, elbows, wrists, hands and fingers. Their grip strength, tactile sensitivity, nerve conduction and manual dexterity are evaluated. Employees are evaluated and should they fall beyond the specified parameters, the engineer is called in to investigate. The result of the investigation is an improvement in the workplace whereby the employee is made more comfortable. The outcome would be a benefit for two stakeholders, namely the employee and the employer. The researcher cannot stress the importance of designing an environment that will reduce fatigue and improve productivity enough [10].

The apparel industry has found that the cost of piecework can be high, for workers who suffer repetitive motion injuries and employers who bear high workers' compensation costs. The Owenby Company (Blairsville, Georgia), a small contract T-shirt factory, experienced that over a four-year period, worker's compensation costs for the nearly 300 employees tripled, and the number of injuries increased eightfold. Worker's compensation premiums skyrocketed 250 percent in just three policy periods. The organisation cut its costs dramatically through ergonomic improvements. In 1993, Owenby launched FOCUS: Forming Owenby Company's Ultimate Safety. The company called in Travelers Insurance representatives to work with employees at its facilities in Blairsville and in Andrews, North Carolina. FOCUS team members helped Owenby employees who cut and sew the T-shirts to examine their workstations and find ways to adjust them to fit properly. In the first seven months of the project, the company was rewarded with an 85 percent drop in paid claim costs. The average cost per claim has been reduced by 70 percent over the long term [14].

Integrating ergonomics into a plant's culture can cut worker's compensation costs, reduce lost time, improve productivity and quality and strengthen labour-management relations. The best way to make ergonomics an integral part of the plant culture is to develop a plant-wide program. Successful ergonomics programs share features that are critical for their success. The two most important are support

of top management and direct operator involvement. In addition to these two elements, successful ergonomics programmes share several other features. Goal setting should specify the reasons for establishing a programme and the measurements by which program success will be evaluated. A game plan is another necessary component; it lays out guidelines for how the programme will function. Evaluating programme results and communicating those results are also important. Finally, every employee in the plant should receive some ergonomics training [12].

In a cross-sectional survey, health complaints among 418 labourers in 15 Indian tanneries were studied. Low-back pain, asthma, dermatitis, and chronic bronchitis were the most frequently reported complaints in the 12 months prior to the survey. In general, beamhouse workers reported the highest occurrence of the above illnesses, but only chronic low-back pain was significantly elevated compared with workers in the finishing departments. When using individual exposure estimates, clear associations were found between manual lifting over 20 kilograms and low-back pain, and skin exposure and dermatitis. Frequent lifting of loads was also associated with self-reported asthma. About 44% of the labourers reported at least one period of sickness absence, and 17% were involved in a serious occupational accident that required a visit to the local physician. Logistic regression analysis showed that sickness absence occurred more often in small tanneries and also was significantly associated with lower-back pain and occupational accidents [6]. Ergonomics is designing things better, or integrating better work methods, work practices, and equipment to humans. He feels that industrial engineers have spent a lot of time on materials, on the process, and on the machinery side, but they've not thought enough about the human and how the human functions. The researcher is in total agreement with this situation due to his exposure in the clothing industry [7].

Typical losses from the failure to apply constructive ergonomics include:

- Lower production output
- Increased lost time
- Higher medical and material costs
- Increased absenteeism
- Low-quality work
- Injuries, strains, fatigue
- Increased incidence of accidents and errors
- Increased labour turnover
- Less spare capacity to deal with emergencies
- Reduced productivity
- Reduced competitiveness

C. Why is there an increased interest in ergonomics?

The increasing interest in ergonomics can be attributed to a number of factors. The most obvious are the rising costs associated with work-related injuries or illnesses. Legal policies and procedures are being regulated in all industries around the world. There is pressure from labour unions and

insurers which have increased employee awareness. This is focussed around the creation of an environment conducive to the task performed and there is mounting evidence that ergonomics programmes can positively affect quality and productivity. These issues combine to make ergonomics an important issue. Worker injuries and their subsequent costs, both direct and indirect, often are the result of some problem with the interface between a worker and a machine system. As technology improves, it leads to increases in automation, so too have work-related illnesses increased – witness the tremendous rise in cumulative trauma disorders, the fastest growing category of workplace trauma. These injuries are common occurrences in materials-handling applications, particularly in assembly line-type work. Causes include poor or unnatural postures, static postures, excessive force required to perform a task, repeated movement at high frequency, insufficient recovery time between repeated movements, vibration and cold temperature [1;11;13;].

In the South African context, very little or nothing constructive has been done to curb work related injuries. According to "nurses" in the clothing fraternity in SA, when people are ill, they basically visit their general practitioners and are given medication for the relieve of their illnesses. There are no investigations into the cause of their respective illnesses. Currently, the researcher has found that general practitioners cannot divulge information regarding their patients due to the Aids epidemic. In the United States, Japan and Germany, a number of the Occupational Health and Safety fines have resulted from investigations requested by labour unions. Increasing media attention, government and insurer-sponsored education initiatives and the growing number of fellow employees who are affected by ergonomic-related illnesses have increased general awareness about ergonomic-related hazards. This increased knowledge will result in further pressure for appropriate ergonomic management [12;31].

The ergonomics problem has become so serious that fines are issued to organisations. Direct medical and compensation costs are being incurred by all stakeholders as a result of poor ergonomic management which represent a significant loss and could have a detrimental effect on profits. There are, however, additional losses associated with ergonomically-induced injuries and illnesses. These are the costs associated with absenteeism, restricted work day cases (workers can return to work, but not to their regular job), turnover and retraining [2;3;7].

III. DISEASES ASSOCIATED WITH POOR ERGONOMICALLY DESIGNED WORKPLACES

A. Cumulative trauma disorders

Work related musculoskeletal disorders of the neck, shoulder and upper limb can be collectively known as repetitive strain injuries (RSI). These disorders can be defined as physically orientated injuries that have developed over a period of time as a result of repeated biomechanical or

physiological stresses on a specific body part. CTD is a collective term for syndromes characterized by discomfort, impairment, disability, or persistent pain in joints, muscles, tendons and other soft tissues. Other terms, which are also used to describe these disorders, include repetitive trauma injuries (RTI), repetitive strain injuries (RSI), musculoskeletal disorders (MSD), and occupational overuse syndrome. Since these injuries develop over relatively long periods of time (months or years), it is difficult to determine how often CTDs occur. CTDs are generally considered to be work related. In other words, these disorders tend to be more prevalent among working people than among the general population [39;35;27].

According to Dillard and Schwager [19] during the working years (ages 18 to 64) more people are disabled from musculoskeletal problems than from any other category of disorder. According to medical scientists, the majority of these musculoskeletal injuries are not the result of accidents or sudden injuries, but rather develop gradually as a result of repeated microtrauma. No uniform label has been adopted; however, they are most commonly referred to as repetitive strain injuries, repetitive motion injuries or cumulative trauma disorders (CTDs). The latter term is perhaps the most descriptive and indicates the cumulative nature of such illnesses as they develop gradually over a period of weeks, months or even years. Trauma refers to the bodily injury from mechanical stresses, and often is only a microtrauma initially.

On evaluation of CTD's, some of the reasons for the increase in the number of people suffering from this disease could be attributed to the following issues which include among others, change in technology, an aging workforce, decreased physical capacities of new workers, lower worker turnover, increased awareness, and change in reporting methods. An increase in the number of CTD cases means the associated cost has also increased significantly [23].

Alexander and Pulat [5] summarizes the relevant research in the area of CTDs, where it is emphasized that there are basically four occupational risk factors associated with the development of CTDs. These are awkward postures, excessive manual force, high rates of manual repetition, and task duration (or inadequate rest). Static loading has also been observed to increase the risk of CTDs. Static loading occurs when muscles are required to generate tension without movement. Static work is not very efficient and causes the muscles to fatigue rapidly. Vibration is another variable, which has been implicated in the development of CTDs. Vibration causes constriction of blood vessels in the fingers as well as numbness and swelling of the hand tissues. This leads to a reduction in grip strength. Any job, which involves one or more of these risk factors, will have a high probability of causing CTDs depending on the severity of each factor.

The potential for CTDs development increases when leisure time activities such as sewing, gardening, and woodworking continue to strain the ligaments and muscles. In addition, as the mean age of the working population increases, strength and flexibility decrements are visible.

These are also important factors which can contribute to the development of CTDs. Jana [27;28] outlined several of the common forms of upper extremity CTDs. These can be classified into three major categories: tendon disorders, neurovascular disorders, and nerve disorders.

B. Tendon disorders

The tendon is a specialized type of connective tissue, which serves to attach muscle to bone. Tendons are surrounded by sheaths of fibrous tissue in order to protect the tissue from friction in certain areas. The sheath contains a synovial membrane which facilitates gliding of the tendon during mechanical actions. Minor disorders of tendons and their sheaths are very common [23].

C. Tendinitis

Tendinitis is inflammation of the tendon occurring from repeated action of the muscle/tendon unit. Since tendons have virtually no blood supply, they are incapable of self-repair and damage becomes incremental. The accumulation of minor damage results in a roughened, nubby tendon, which may produce friction and irritation of its sheath. Ultimately, the tendon may become so weakened that it ruptures. Without rest or sufficient time for tissue to heal, the tendon may be permanently damaged [23].

Tendinitis is most likely to occur in areas where the tendon is restricted anatomically, such as in bony channels and tunnels. Examples would be the thumb tendons in the radial groove at the wrist or in tendons which support a joint, such as the rotator cuff of the shoulder [37;38].

D. Tenosynovitis

Tenosynovitis is fairly common in finger and wrist tendons or in other areas where the tendon excursion from the synovial sheath is long (usually two or more inches). In such situations, repetitive motion (gliding) of the tendon within the sheath may overwhelm the lubricating ability of the sheath. This will ultimately result in an inflammatory reaction within the tendon sheath [37].

E. Bursitis

Bursae are anti-friction devices found throughout the body where bony prominences are close to the skin surface and friction from outside the body or where tendons and ligaments may rub against the prominences. In the presence of high degrees of friction, the bursae will oversecrete lubricating fluids and bursal sacs will become enlarged and distended. If friction persists, the walls of the sac will thicken and become inflamed [38].

F. Ganglionic cyst

Caused by the swelling of a tendon sheath with synovial fluid, a ganglionic cyst is common and is generally related to wrist usage. Though rarely causing symptoms of nerve compression, such a cyst can often be painful and is usually treated by aspiration or by surgical removal if the ganglion

recurs [38]. Neurovascular disorders are those CTDs which involve both the nerve and adjacent blood vessels.

G. Thoracic outlet syndrome

Probably the most common form of neurovascular disorder is the thoracic outlet syndrome. Thoracic outlet syndrome is a general term for compression of the nerves and blood vessels as they pass through the neurovascular bundle between the neck and shoulder. Also known as cervicobrachial disorder, thoracic outlet syndrome is generally thought to result from heavy workloads combined with repetitive straining or unnatural static positioning of the arms. Typical symptoms of thoracic outlet syndrome include numbness and tingling in the fingers and hand, as well as a sensation of the arm “going to sleep”. The blood pulse at the wrist may also become weakened [38].

H. Vibration syndrome

Sometimes referred to as vibration-induced white finger, Raynauds syndrome, or traumatic vasospastic disease, vibration syndrome is characterized by episodes of blanching (whiteness or paleness) of the fingers due to closure of the digital arteries. Due to the blockage of circulation in the fingers, coldness and pain are often associated with vibration syndrome. The transmission of vibration (varying in acceleration, or power, and frequency) causes this condition from a tool to the hand. It is believed to be in part a vascular disturbance due to changes in the blood vessel walls and in part a nervous disturbance caused by reflex contraction of the smooth muscles of the blood vessels [38].

I. Nerve entrapment disorders

Nerve entrapment disorders occur when repeated or sustained work activities expose the nerves to pressure from hard, sharp edges of the work surface, tools or nearby structures such as bones, ligaments, and tendons.

J. Carpal tunnel syndrome

Carpal tunnel syndrome (CTS) is one of the major forms of cumulative trauma disorders caused by increase of fluid pressure within the tight compartment of the tunnel in the wrist. It is generally attributed to insult, usually compression, of the median nerve within the wrist. Compression of the median nerve is, in turn, associated with repeated or sustained activities of the fingers and hands, often combined with the application of force, as well as pressure from hard work surfaces and sharp edges on hand tools [38].

Although the innervation pattern varies slightly, the primary areas affected by the median nerve include most of the palmar side of the hand, the thumb, and all of the fingers except the ulnar side of the ring and small fingers. Under normal conditions, there is smooth movement of the nerve and tendons accompanying movements of the wrist. However, compression of the nerve will result from flexion and extension movements when the boundaries of the tunnel are compromised or when structures of the tunnel become

enlarged. Initial complaints of CTS include sensations of pain, numbness, and tingling in one or both of the hands at night. The symptoms of CTS may progress until attacks of pain and/or tingling are experienced during the day. At this point, individuals may complain of a general clumsiness or an inability to grasp and hold objects. A significant reduction in work-related measures, particularly grip strength, range of motion, and performance time has been demonstrated. The exact incidence rate of CTS in industry is unknown; however, many industries now claim that CTS is among their most disabling and costly medical problems [37].

K. Risk factors associated with CTS

There are a number of risk factors, which have been associated with the development of CTS. These risk factors can be divided into three broad categories:

- occupational risk factors;
- systemic conditions;
- non-occupational risk factors.

The occupational risk factors most frequently associated with CTS include force, repetitiveness, and posture. When a job requires high levels of force and repetition, more muscle effort is required. This increases the need for increased rest periods or recovery time. Without sufficient recovery time, cumulative injuries are likely to occur. The amount of time required to perform a task is also thought to be an important variable in the development of CTS [37;38;40].

IV. METHODOLOGY

The research comprises a qualitative exploratory and descriptive design [17]. The purpose of exploration was to gain insight into the current phenomenon of by systematic observation and discussions at a sample of clothing manufacturers in Kwa-Zulu Natal. A case study type questionnaire was developed to obtain information within the industry in Kwa-Zulu Natal. Some information was considered confidential by the manufacturers and was not provided. For the purposes of this investigation, clothing manufacturers were categorized into small, medium and large manufacturers. Personal interviews and direct observation were used to gain insight into the issues of strategies employed. It was extremely difficult to obtain information from all the stakeholders as time was a crucial issue in a highly competitive production environment. Workers were busy with producing output while the researcher spoke to them on a one on one basis. Groups of workers were spoken to during breaks. Interviews were conducted with middle and senior management on a one on one basis in their offices. However, all interviewed personnel forbid the exposure of their names to any person within and outside the organisation [17]. In addition, the researcher utilised information from public and private sector data.

The sample in the investigation comprised clothing manufacturers in the Durban and surrounding areas totalling

146 factories of a possible total of 416 factories. A total number 568 people participated in the study. To initiate and speed the investigation process the researcher conducted telephonic interviews, in-factory interviews with managers, supervisors and shop-floor employees. To obtain an insight into current manufacturing practices, the researcher visited factories for approximately five hours and recorded while observing the entire chain of activities from input raw materials to the dispatching of finished products. A semi-structured questionnaire was also used during the interview process. Certain questions were considered confidential and no answers were given.

V. RESULTS AND DISCUSSION

A. Introduction

Demographic data indicates that 55% of the respondents were between 40 and 50 years old who have been machinists for approximately 20 years, 25 % were between 20 and 35 years. The remaining respondents were below 20 and above 50 years old. The sewing production area was predominantly female and breadwinners of the family. The other areas of the production system, namely receiving of raw materials, cutting, pressing and dispatch were male dominated. The majority, 87% of the respondents completed their senior certificate examinations and were financially unstable to attend higher education institutions. Due to the geographic location, 62 % were from an Indian heritage while 38% were from the black African heritage with a number of foreign nationals [29].

B. Findings

The results of the survey indicated there were ergonomic problems throughout the value chain of clothing manufacture. The cutting room was indicated a major risk area as operators handle cutting machines such as a band knife and a straight knife. Operators were often seen stretching out with lifted ankles in order to complete the cutting operation. A slight loss of focus could lead to catastrophic consequences as it was reported that operators have lost fingers, hands and some were even killed in an accident in the cutting room.

In the sewing section, piercing of the finger was the most common injury experienced by operators. In addition, if operators are dealing with difficult fabrics such as denim, there is the possibility that the needle gets bent and crashes against the feed-dog, thus causing it to break and ricochet towards the eye, causing fatal injury. Injury to the index and middle finger are common with machinists [20;21].

Accidents in the pressing area occur with due to a lack of safety measures being implemented. Operators have been reported to have burnt their hands, feet, torso and face in the course of work. Unsafe acts of workers have lead to serious injuries. This can be categorized as follows:

- Loose clothing
- Hair left untied
- Jewelry
- Improper body movements
- Improper moving of materials
- Lack of use of safety devices
- Improper storage of material

The body has the ability to recover from minor stress. Research indicates that when recovery time is insufficient and work is highly repetitive with forceful or awkward postures, the worker is at risk of developing CTD. Research in apparel manufacturing conducted on musculoskeletal injuries by concluded that sewing machine operators experienced significant job-related musculoskeletal pain. Operators' complaints were specific to the neck, shoulders and lower limbs. According to their research, musculoskeletal complaints were attributed to the working posture of the sewing operator. Specific illnesses identified were tendonitis, carpal tunnel disorders and neurovascular complications [39].

In a more recent study, factors which have been linked to sewing operators' poor postures were visual demands of the work, the workstation design and inadequate seating. It has been observed that insufficient lighting of the work area required the operators to lean in towards their work area resulting in a hunched posture. The workstation design was such that the workers had to adapt to it, rather than having the workstation designed for the worker. Worktables did not allow enough surface area for workers to rest their upper limbs, and workstation height led to awkward postures. Because sewing has traditionally been done in a seated position, the design and benefits of ergonomically designed chairs have been studied by a number of researchers. Although using a chair for industrial sewing operations reduces body fatigue, it may also introduce excessive musculoskeletal stresses if the sitting posture is supported improperly. Musculoskeletal stresses can be lessened if a larger trunk-thigh angle is maintained at 135 degrees with the lumbar spine in neutral position [19].

During a series of visits, interviews were conducted with 568 volunteer operators that were representative of the target jobs in the plants. These interviews covered:

- (1) musculoskeletal discomfort;
- (2) characteristics of the work environment;
- (3) characteristics of the workstation, chair and job;
- (4) training;
- (5) environmental measures.

Environmental measures with regard to illumination, temperature and noise were taken at sample workstations throughout the plants.

TABLE 1. RESULTS OF INTERVIEWS (OVERALL)

n = 568 n = the number of respondents	RECEIVING AND CUTTING DEPARTMENT n = 125		MACHINING n = 313		PRESSING n = 85		FINISHING AND DESPATCH n = 45	
Accidents	15	12	178	56.8	55	64.7	5	11.1
Upper back pain	89	71.2	291	93.0	85	100	15	33.3
Neck pain	76	60.8	266	85.0	85	100	8	17.8
Shoulder/Wrist pain	87	69.6	238	75.0	68	80	6	13.3
Working posture	92	73.6	186	59.4	75	88.2	2	4.4
Illumination	67	53.6	128	40.8	65	76.4	0	0
Seating	10	8	285	91.0	0	0	0	0
Repetitive manipulation	65	52	210	67.1	80	94.1	0	0

VI. DISCUSSION OF RESULTS

The above table (Table 1) provides an overall assessment of the various sections of the clothing manufacturing environment. It can be noted that the people that are most prone to ergonomic discomfort are the machinists who are reported to have 56.8% of the accidents and an overall discomfort index of 73%. Therefore it became necessary to develop a questionnaire focussing on the machinists only. The results are provided in Table 2.

A. Musculoskeletal discomfort

During the interviews, machinists reported that they experienced pain in their upper backs (93%), shoulders/wrists (85%) necks (75%) (Table 1). This reported prevalence of neck, shoulder, and back discomfort was consistent with the results of the questionnaire (93%) (Table 2).

B. The working posture

Much of the reported discomfort in the back and neck could be attributed to the working posture of the seated operators (healthcare professional). In response to job and workstation characteristics, it was observed that operators typically adopt a hunched working posture. An analysis of the postures indicated that 60% of the machinists tilted their heads more than 20 degrees throughout the cycle (Table 1). Several workers stated that this posture was necessary to maximise production. Such postures have been cited as a factor in muscle fatigue and discomfort [24]. The tendency of operators to work in this hunched position can be attributed to

at least three factors, namely the visual demands of the work, the geometry of the workstation and inadequate seating.

C. Illumination

Most sewing operations are visually demanding, requiring the precise stitching of thread into a fabric of the same colour, so that there is little or no visual contrast. Evaluation by the internal healthcare worker revealed that 50% of the machinists had poor eyesight and required thorough evaluation by an optometrist. Machinists were advised to take the necessary action to rectify their eyesight as soon as possible, as poor eyesight could lead to accidents in the workplace. Another issue that was noticed was the colour of the lighting. On questioning line managers it was found that fluorescent tubes emitted a slightly yellowish light and as each failed tube, it was replaced by more natural light.

D. Workstation geometry

The hunched position in which operators tended to work also suggested a potential conflict between workstation geometry and individual operator dimensions. Analysis indicated that the machine treadle was typically located too close (mean = 15 cm) to the proximal edge of the work surface. Most commonly, operators responded by positioning the chair away from the work surface in order to allow a knee angle of 110 degrees or greater. From this position, the mean distance from the back of the chair to the point of operation (POO) was only 3 cm less than the arm length of the 50th percentile operator. To compensate for these workstation problems, operators leaned forward to maintain adequate visual and manual access to the POO.

TABLE 2. RESULTS OF ANALYSIS OF 313 COMPLETED QUESTIONNAIRES FOR MACHINISTS ONLY

Criteria		
Seat height	32% unacceptable	68% acceptable
Aches and pains	93% experience pains	7% no pain
Adjustable foot rest	90% not adjustable	10% adjustable
Seat adjustability	100% not adjustable	0% adjustable
Working height	27% poor	73% satisfactory
Space	69% restricted	31% satisfactory
Machine operation	33% strenuous	67% easy
Accessibility of controls	37% not accessible	63% accessible
Skill level	86% demanding skill	12% low skill
Work organisation	40% disorganised	60% organised
Posture	48% hunched position	52% natural posture
Nature of work	83% repetitive	17% non-repetitive
Illumination	48% very poor	52% acceptable
Air flow	64% poor flow	36% acceptable
Physical strain	90% strenuous	10% not strenuous
Comfort level	76% uncomfortable	24% comfortable
Climatic conditions	61% unfavourable	39% favourable

Another factor that limited operator access to the workstation was the location of various obstructions (motors, pneumatic equipment, and machine guards) beneath the work surface. While typical recommended lateral knee room is approximately 46 cm, the presence of these obstructions limited the available space to less than 26 cm in some cases.

E. Seating

The vast majority of operations were performed in a seated position. Seating encountered in the sewing environment typically consisted of straight-backed wooden or metal chairs without cushions for reducing body compression and fatigue. They also lacked adjustable backrests, and often were of improper height. Machinists (91%) (Table 1) customised their chairs by using handmade cushions on the pan and backrest in order to adjust the height and increase pliancy. Most cushion adjustments increased seat height by 3-6 cm when compressed. Although this eased the situation a little, machinists confirmed the urgent need for comfortable, adjustable chairs.

F. Repetitive manipulation

The primary risk factor for the development of trauma disorders is the frequency with which motions are repeated. On the basis of observation and interviews with an experienced methods engineer, the sewing jobs were classified as requiring high, medium, or low amounts of repetitive manual manipulation. While the classification was somewhat subjective, it was closely related to the frequency of changes in hand and wrist posture. High degrees of manual manipulation were associated with higher levels of physical discomfort almost throughout the day. The greatest discomfort levels were concentrated in the neck, upper and middle back, right shoulder and hands. Seventy-three percent of the high-manipulation workers reported pain in their right hands. This was the highest discomfort frequency identified in the analysis, and is consistent with the findings of Jana [27;28], which indicated a significant relationship between hand pain and repetition rates.

The cycle time of jobs ranged from 25 to 150 centiminutes, with the majority falling within the 35 to 75 centiminutes range. An average of 29 left-hand and 25 right-hand posture changes per cycle was recorded. The most frequent hand and wrist postures included pinch (lateral and pulp), ulnar deviation, flat press, extension and flexion.

G. Training

In the case of a few plants (5%) sewing operators received training in a training school. The other plants offered on-the-job training where necessary, but employment policies favoured experienced operators. Training periods varied from a few days to up to six months. None of the plants under investigation provided their supervisors or training staff with specialised instruction in effective training techniques. There was evidence that improvements in operator training were being made, especially in the case of newly appointed

workers. Higher percentages of younger operators reported receiving job-methods training by way of visual aids or videotapes, as well as training on posture, lifting and safety issues. After the initial hour or so of intensive training, return visits by the trainer/supervisor were sporadic. One plant posted a daily learning curve on the novices' workstations, but even this degree of performance feedback was unusual [2;3;4].

H. Questionnaire results

The physical difficulty of the sewing operation (90%) correlates with the skill levels required in the performance of work (86%) and the product-orientated repetitive nature of work (83%). It can be deduced that effective work performance requires a high level of skill and that the work is physically demanding and repetitive. The easy operation of the machine (67% stated that it was easy to operate) correlates with accessibility of all machine controls (63% stated that all controls were accessible). It can be confidently stated that the machine is easy to operate. The responses regarding airflow (64% stated that it was insufficient) correlate with those regarding air temperature (76% stated that it was uncomfortable), which further correlates with the responses regarding climatic conditions, which 61% of the respondents described as unfavourable.

VII. RECOMMENDATIONS

THE MACHINISTS' WORK ENVIRONMENT

It is imperative that these ergonomic factors be considered as the machinist task is performed while seated. All diseases mentioned in section 4 could be reduced if the following requirement of motion economy is implemented.

Seating requirements

- **Seat height**

The height of a seat should not exceed the popliteal height of its user (i.e. the height of the underside of the knees). For a resting chair, where the user may wish to stretch their legs, a lower seat is preferable. The popliteal height of a 5th percentile of adult women (wearing typical outdoor shoes) is 400 mm. Thus the height of a non-adjustable chair should not exceed 400 mm, or 425 mm at the most [35;37]. An excessively low chair makes standing up and sitting down more difficult and requires greater forward leg room for the comfort of tall people.

- **Seat depth**

The depth of the seat, measured from the front edge of the backrest, should not exceed the buttock-popliteal length of a small user (5th percentile women = 435 mm).

A seat that is too deep will inevitably deprive the person using it of the full benefit of the backrest. The person will either have to lean back in a flexed position with the lumbar region essentially unsupported, or will have to sit forward and lose contact with the backrest altogether. Neither is satisfactory. A depth of approximately 380 mm

is usually recommended [37].

- **Seat width**

This is determined by the need to accommodate the hips and lower trunk. A width of 410 mm will fit all but the broadest person, although 50 mm should be added to this to allow for clothing and the contents of pockets. Maximum widths are likely to be constrained by space requirements at the workplace, particularly if seats are placed next to each other in a row.

- **Upholstery of the chair**

As a very rough guide, the upholstery of a chair should have a space of about 2.5 cm between body and chair structure when compressed. Upholstery materials should be porous (plastic and wooden chairs may become unpleasantly clammy in hot weather).

- **Workspace**

Ideally industrial workstation design should satisfy the system's performance requirements, as well as the requirements of the human user. Generally, an industrial workstation is a small working area in which workers perform assigned tasks. The terms workstation, workspace and work environment are often used interchangeably and include chairs, tables, machines, tools, actual product, regular and protective clothing, lighting and climate. The physical dimensions of the workspace are very important because small changes may have a considerable impact on productivity and occupational safety and health. A well laid-out workplace, or a well-designed piece of equipment, is one in which the operator can see and quickly and easily reach all the items necessary for the effective completion of a task. This can be performed in a posture or postures in which there is no discomfort or strain.

- **Worktable requirements**

The worktable should be of the height that suits the operator, whether he/she stands or sits at the worktable. The most favourable height for handwork is 10 -15 cm below elbow level. In the clothing industry there are variations in the size of the worktable, and recommendations should be made on a specific minimum and maximum. The current dimensions are as follows:

Worktable length: 100 cm

Worktable width: 50 cm

Worktable height: 71 cm (for sitting position)

To determine proper workstation height, the following may be considered:

- Make available several workstation heights.
- Adjust the work on the workbench size [10].

The surface of the worktable should be well finished, creating a smooth surface with well-formed corners to prevent damage to fabrics, while at the same time creating a safe and comfortable surface.

The following principles should be considered when

deciding on workstation dimensions:

- Consider body measurement, as well as range and strength of movements of the kinetic elements involved in a task.
- Take account of the full range of body dimensions of the working population involved in a specific task.
- Recognise differences relating to sex, ethnic group and educational or social background. Each of these may affect specific types of manipulative skills.
- Determine, by way of biomechanical analysis, the optimal position of an operator with regard to equipment controls.
- Provide maximum postural freedom in task design, especially for repetitive work situations.
- Avoid standing in full foot and torsion or sideways bending of the trunk.
- Refrain from performing a task on a strip 7.6 cm wide from the border of the bench that is closest to the operator [6;7;9].

Principles of motion economy

The following principles of motion economy in the workspace should be considered:

- position tools and materials to reduce searching;
- arrange materials and tools to permit the best sequence of motions;
- use gravity feed, bins and containers to deliver the materials as close to the point of use as possible;
- locate tools, materials and controls within the normal working area if possible, otherwise within the maximum working area;
- use 'drop deliveries' or ejectors wherever possible so that the operator does not have to use his/her hands to dispose of the finished work; and
- make the height adjustable to allow alternate standing and sitting [14;38].

Man-machine interface

The interaction between the operator and the machine occurs via control devices (knobs, levers, pedals, keyboards, etc.) and information sources or displays (dials, counters, lights, charts, etc.). The proper design of this interface has important implications for the performance of the total system and for the safety and well-being of the operator [38;41;42].

Interface layout

The most important and most frequently used hand control should ideally be located within an area that extends from approximately 25 cm to 75 cm above the seat reference point and 38 cm to each side. When displays and controls are used in a fixed sequence, they should be laid out accordingly and grouped together for their related functions. The clearances between neighbouring controls should be sufficient to prevent accidental activation. Since no single control device can be rated as good in respect of all the operational criteria, some degree of compromise and

subjective judgement is required when selecting controls. Furthermore, all clothing manufacturing equipment is imported and seems to have been built with ergonomic considerations in mind. Unfortunately this is not the case as experienced by the researcher as modifications improve operator movements and machine time. [8;12;15].

VIII. CONCLUSION

It has been found that ergonomics is no longer just a buzzword; it is going to be around for a long time because it makes good business sense. It has become evident that companies are realising that making ergonomic changes that may prevent major work-related injuries (proactive ergonomics) is much more cost effective than introducing such changes once major work-related injuries have already occurred (reactive ergonomics). In other words, they are realising the advantages of paying for ergonomic changes up front, rather than pay later whilst running the risk of diminishing the quality of life of their workers [40;41;42].

This study made it clear that ergonomics should actually be common sense. If a company can reduce work related injuries, productivity would increase simply because employees are healthier with less absenteeism. It also provides an excellent opportunity to decrease waste and increase productivity. During the course of the study it was very important to determine what the ergonomic problems were. The framework (fundamental principles) that was created provides a good indication of the areas on which the work-study officer should concentrate during the intervention for constructive input with a view to improvement. In order to ensure that the benefits of success would be reaped, any implementation (training) must include a corporate cultural change focusing on education and training. Ergonomics is a constantly growing field, and as long as people are used as the primary source of labour, there would be an endless need to make them comfortable through ergonomic enhancements in the workplace[16;43].

The challenge for an apparel production manager is to minimise input costs while achieving improved productivity and remaining flexible and meeting customer demands. Labour savings and increased productivity could be achieved by reducing the ratio of number of workers to number of machines. A survey conducted by the Institute of Industrial Engineers reported that 38 percent of the respondents observed increased productivity as a result of the development of effective ergonomic principles. Systems innovations resulted in a 37 percent improvement in productivity, while the use of robotics accounted for a 29 percent improvement in productivity. Increased productivity for human activity could be achieved through multitask operations (i.e. cross-training operators) and other methods that will allow the same amount of work to be done in less time. New sewing systems (eg. teamwork modular manufacturing systems) should meet these requirements. In teamwork modular manufacturing, a reduction in the need for

labour (i.e. number of workers) results in a corresponding rise in productivity and savings [14;15;25].

In the South African clothing industry, management commitment in terms of attitude, managing in a diversified workplace and the allocation of resources are essential to the process of ergonomic management. Through simple, innovative and creative thinking, the current status of the industry could be improved through the application of ergonomic principles. The researcher would like to conclude by emphasising the need to implement ergonomics in a project-by-project approach, using a systematic method of application[30].

REFERENCES

- [1] Awasthi M. and Singh A. 2003. Global competitiveness hinges on product quality. *The Textile magazine* 44: 42-43.
- [2] Abernathy, F et al., 1999. *A stitch in time: Lean Retailing and the Transformation of Manufacturing - Lessons from the Apparel and Textile Industries*, Oxford University Press, New York, NY.
- [3] Adewole, A.2005. Developing a strategic framework for the efficient optimization of information in the supply chains of the UK clothing manufacture industry. *Supply chain management: An international Journal*.10:5. Emerald Group Publishing Ltd.
- [4] Allnoch, A.1997, IE knits productivity with ergonomics tool, *IIE solutions*. 29:16-17.
- [5] Alexander, DC. Pulat, BM. 1991. Eds. *Industrial Ergonomics: Case Studies*, Industrial Engineering and Management Press. Georgia
- [6] Bennet, M.2003, Organising in the informal economy: A case study of the clothing industry in SA, *Small enterprise development (SEED) working paper no. 37*.Geneva. ILO.
- [7] Bell.T. 2006,Clothing chains wait over quotas is hypocrisy. *SA Media*. University of the Free State. *The Star*. 15 Sept.
- [8] Berman, K. 2005. Clothing-import crisis generates bizarre heat. *Business day*. Johnnic communications. I-net Bridge.
- [9] Barnes, J. et al.2005. An analysis of the MIDP's contribution to the success of the South African automotive industry – Policy lessons for the clothing, textile and paper and paper products industry. *NPI Research Report*.
- [10] Bheda R. 2004. Improving working conditions and productivity in the garment industry. *Contact communications*. *Stitch world*. New Delhi. India.
- [11] Botha, E. 2000. Global competitive strategy imperative for local business. *Management Today*. 6.
- [12] Byrne, C. Rigby, D. 2000, *International Labour Organisation*, Geneva
- [13] Bolisani, E and Scarso, E.1996. *International manufacturing strategies: experiences from the clothing industry*. *International Journal of Operations & Production Management*. 16:8 pp71-84. MCB University Press
- [14] Buxey, G. 2005. Globalisation and manufacturing strategy in the TCF industry. *International Journal Of Operations management* 25:2. MCB university press.
- [15] Buxey,G. and Kosmider, R. 1997. Strategies for survival following tariff reform. *Industrial Management and Data Systems*. V 97 No. 6. MCB University Press.
- [16] Chan, J.W.K., Burns, N.D.2002, "Benchmarking manufacturing planning and control (MPC) systems: an empirical study of Hong Kong supply chains", *Benchmarking: An International Journal*, 9(3), 256-77.
- [17] Cooper, DR and Schindler, P. 2011. *Business Research Methods*. McGraw-Hill. New York
- [18] DTI. 2005. Driving competitiveness in South Africa: The integrated industrial strategy for sustainable employment and growth. Pretoria.
- [19] Dillard, BG. Schwager, TF.1997. Ergonomics in the clothing industry. *International Journal of Clothing Science and Technology*. MCB University Press. 9(4):285-300.
- [20] Echikson,W. 2006. SA textile industry gets frayed by Chinese Imports.

- SA Media. University of the Free State. Citizen. 8 September. Ref 14356.
- [21] Edwards, L., 2001. Globalisation and the skill bias of occupational employment in South Africa. *South African Journal of Economics*, 69, 1: 40-71.
 - [22] Forza, C and Vinelli, A. 2000. Time compression in production and distribution within the textile-apparel chain. *Integrated manufacturing systems*. 11:2. MCB University press.
 - [23] Galer, I. 1995. *Applied Ergonomics Handbook*. Second Edition Butterworths and Company. London.
 - [24] Glock, RE and Kunz, GI. 2005. *Apparel manufacturing: sewn product analysis*. 4th ed. Prentice Hall.
 - [25] Gryna, F.M. 2001. *Quality Planning and Analysis – from product development through use*. 4th ed. New York: McGraw-Hill.
 - [26] Inggs, M. 2007. Clothing retailers seek an alternative to China. SA Media. University of the Free State. 17 January
 - [27] Jana P. 2008. Ergonomics in apparel manufacturing I . Importance and impact of ergonomics. *Stitch World* 6: 42-47
 - [28] Jana P. 2008. Ergonomics in apparel manufacturing II. Workplace ergonomics in apparel industry. *Stitch World* 6: 42-49
 - [29] Kahn, B. 1998. Assessing South Africa's Competitiveness: Is the Reserve Bank's Measure Misleading. *LSE Centre for Research and Finance in Southern Africa Quarterly Review*, no. 4.
 - [30] Kilduff, P.2000. Evolving strategies, structures and relationships in complex and turbulent business environment: The textile and apparel industries of the new millinium. *Journal of textile and apparel, technology and management*, 1(1) September.
 - [31] Kogi, K. , Kawakami T. 1997. *Environmental Management and Health*. MCB University Press. 8(5): 188-190.
 - [32] Krajewski, LJ. and Ritzman, LP. 1996. *Operations Management: Strategy and Analysis*, 4th ed., Addison-Wesley, Reading, MA.
 - [33] Kraak, A. (ed.) (2000). *Changing Modes: New Knowledge Production and Its Implications for Higher Education in South Africa*. Pretoria: HSRC.
 - [34] Kruss, G. 2004. Employment and employability: expectations of higher education responsiveness in South Africa. *Journal of Education Policy* Vol. 19, No. 6, November 2004 Taylor & Francis Ltd.
 - [35] MacLeod, D.1995. *The Ergonomics Edge: Improving safety, Quality, and Productivity*. New York: Thompson Publishing.
 - [36] Mathews, S.C. 2010. *Business Day*. I-Net Bridge. Johannesburg
 - [37] Osborne, DJ. 1991. *Ergonomics at work*. 2nd edition. John Wiley and Sons. New York.
 - [38] Pheasant, S. 1991. *Ergonomics, work and health*. McMillan Press Ltd. London. 7-13.
 - [39] Pulat, B.M. & Alexander, D.C. (eds). (1991), *Industrial Ergonomics : Case Studies*. Industrial Engineering and Management Press. USA. 3-6.
 - [40] Ramdass, K .2003. The role of ergonomics in the clothing manufacturing industry, with specific reference to seamstresses, Technikon Witwatersrand, Johannesburg, South Africa.
 - [41] Ramdass, K. 2009. A engineering management framework for the clothing industry in South Africa with a focus on Kwa-Zulu Natal, University of Johannesburg, South Africa.
 - [42] Render, J. & Heizer, B.2011. *Principles of Operations Management*. 6th edition. New Jersey: Upper Saddle River, Prentice Hall.
 - [43] Stevenson, WJ. 2011. *Operations Management*. 9th edition. Mcgraw Hill. New York.
 - [44] Ward, PT. and Durray, R. 2000. Manufacturing strategy in context: environment, competitive strategy and manufacturing strategy, *Journal of Operations Management*, 18(2), 123-38.